

8. The theory is applied to Professor Weldon's measurements on Naples crabs. It is shown that his material is absolutely homogeneous, all roots of the nonic for No. 4 organ leading to imaginary solutions, even its real root. On the other hand, it is shown that the Naples crabs are breaking up into two different sized families, owing to evolution in their foreheads. The theory is further applied to Mr. Thompson's measurements of the carapace of prawns (1,000 measurements). It is shown that we have in the measurements a very small percentage of anomalous results, corresponding to prawns deformed in this organ, or that there is, on the other hand, a small but unstable giant population mixed with the normal population. Which of these results is to be considered the true answer to the problem can only be determined after an analysis of the frequency curves for other organs.

From the mathematical standpoint, the memoir illustrates the determination of the roots of equations of the ninth degree, and the calculation of the higher moments of curves.

IV. "Experiments in Heliotropism." By G. J. ROMANES, F.R.S. Received October 2, 1893.

I cannot find in the literature of heliotropism that any experiments have hitherto been made on the effects of interrupted illumination, when the periods of illumination are rendered as brief as possible—*i.e.*, instantaneous flashes of light. Accordingly I have conducted an extensive research on heliotropism, where the flashes have been caused either by means of electric sparks in a dark room, or by the opening of a photographic shutter placed before the plants in a camera obscura with an arc light or Swan burner, at a distance of several feet on the other side of the shutter. The electric sparks were made either with a Wimshurst machine, induction sparks, or by means of the following contrivance. From the binding screws of the condenser of a large induction coil copper wires were led to a cup of mercury, where, by means of an electro-magnet suitably actuated by clock work, a current was closed and opened at any desired intervals: each break was therefore accompanied by a brilliant spark. A thick plate of glass was interposed between the seedlings and the electrical apparatus. In all the experiments here described the plants employed were mustard seedlings (*Sinapis nigra*), previously grown in the dark until they had reached a height of between 1 and 2 inches. Save when the contrary is stated, in all the experiments comparative estimates were formed by using the same pot of seedlings: during the first half of a comparative experiment half of the seedlings were protected from the light by a cap of cardboard covering half the pot;

during the second half of the experiment this cap was removed, and the pot turned round, so as to expose the previously protected seedlings to the influence of the light. The principal results thus obtained, and frequently corroborated, were as follows.

I. Even having regard to the fact that for equal strengths of a stimulus excitable tissues are more responsive in proportion to the suddenness of the stimulus (or in a kind of inverse proportion to the duration of the stimulus), the heliotropic effects of such flashing stimulation as is above described proved to be much greater than might have been antecedently expected. This was shown to be the case whether the effects were estimated by the rapidity with which the seedlings began to bend after the flashing stimulation was begun, or by that with which they continued to bend until attaining a horizontal line of growth, *i.e.*, bending to a right angle. Thus, at a temperature of 70° Fahr., and in a moist camera, vigorously growing seedlings begin to bend towards the electric sparks ten minutes after the latter begin to pass, and will bend through 45° in as many minutes; frequently they bend through another 45° in as many minutes more. This is a more rapid rate of bending than can be produced in the same pot of seedlings when the previously protected side is uncovered and exposed for similar durations of time, either to constant sunlight, or to constant diffused daylight. This is the case even if the sparks (or flashes) succeed one another at intervals of only two seconds.

II. It would thus appear that the heliotropic influence of electric sparks (or flashes) is greater than can be produced by any other source of illumination. But, in order to test this point more conclusively, I tried the experiment of exposing one half-pot of seedlings in one camera to the constant light of a Swan burner, and another half-pot of similar seedlings, in another camera, placed at the same distance from the same source of light, but provided with a flash shutter working at the rate of two seconds intervals. The amount of bending in similar times having been noted, the pots were then exchanged, and their previously protected halves exposed to the constant and the flashing light respectively. In both cases, the rapidity with which the bending commenced, and the extent to which it proceeded in a given time after commencement, were considerably greater in the seedlings exposed to the flashing than to the constant source stimulation. The same is true if, instead of a Swan burner, the source of light is the sun.

III. Many experiments were tried, in order to ascertain the smallest number of sparks in a given time which would produce any perceptible bending. Of course the results of such experiments varied to some extent with the condition of the seedlings. But in most cases, with vigorous young mustard seedlings and careful observation,

bending could be proved to occur within fifteen to thirty minutes, if bright sparks were supplied at the rate of only one per minute. The most extreme sensitiveness that I have observed in these experiments was that of perceptible bending after half-an-hour's exposure to electrical sparks following one another at the rate of fifty in an hour. This result would appear to indicate that in heliotropism under flashing light there need be no summation or "staircase effect"; but that each flash or spark may produce its own effect independently of its predecessors or successors.

IV. It is noteworthy that, while the heliotropic effects of flashing light are thus so remarkable, they are unattended with the formation of any particle of chlorophyll. In the many hundred pots, and therefore many thousands of plants, which have passed under my observation in this research I have never seen the slightest shade of green tingeing the etiolated seedlings which had bent towards flashing light. On one occasion I kept a stream of 100 sparks per second illuminating some mustard seedlings continuously for forty-eight hours; and although this experiment was made for the express purpose of ascertaining whether any chlorophyll would be formed under the most suitable conditions by means of flashing light, no change of colour in any of the seedlings was produced.

With the exception of those mentioned in the last paragraph, all these results were obtained by using sparks from the coil condenser, as above explained. These sparks were very brilliant, and yielded the maximal results, which alone are here recorded.

V. "Experiments in Germination." By G. J. ROMANES, F.R.S.
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The primary object of these experiments was to ascertain whether the power of germination continues in dry seeds after the greatest possible precautions have been taken to prevent any ordinary processes of respiration for practically any length of time.

The method adopted was to seal various kinds of seeds in vacuum tubes of high exhaustion, and after they had been exposed to the vacuum for a period of fifteen months to remove them from the tubes and sow them in flower-pots buried in moist soil. In other cases, after the seeds had been *in vacuo* for a period of three months, they were transferred to sundry other tubes respectively charged with atmospheres of sundry pure gases or vapours (at the pressure of the air at time of sealing); after a further period of twelve months these sundry tubes were broken, and their contents sown as in previous case. In all cases, excepting that of the clover, the seeds sown were weighed individually in chemical balances, and seeds of